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ACRS Members

PERFORMANCE OF PIPING AND COMPONENT SNUBBERS AND RESTRAINTS

Dr. Bush has provided the attached for the information of  
ACRS members.

Original Signed by  
R. F. Fraley

R. F. Fraley  
Executive Director

Attachments:  
Cy. of Slides re. Piping & Com-  
ponent Snubbers & Restraints

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## PIPING AND COMPONENT SNUBBERS AND RESTRAINTS

### THE PURPOSE OF SNUBBERS

MINIMIZE DAMAGE TO PIPING AND OTHER PRESSURE BOUNDARY COMPONENTS DURING TRANSIENTS SUCH AS MAJOR EARTHQUAKES, WATER HAMMER, PIPE WHIP, ETC., BY LIMITING RAPID MOVEMENT THROUGH MECHANICAL-INERTIAL OR HYDRAULIC PISTON DEVICES.

### THE PROBLEM

1. A HISTORY OF PARTIAL OR COMPLETE INOPERABILITY OF SOME HYDRAULIC SNUBBERS DUE TO LOSS OF HYDRAULIC FLUID OR OTHER CAUSES;
2. CORRECTIVE ACTION BY USNRC THROUGH TECHNICAL SPECIFICATIONS THAT MAY AFFECT PLANT CAPACITY FACTORS;
3. NO DEFINITE ASSURANCE THAT THE PROPOSED "FIXES" YIELD THE DESIRED LEVELS OF RELIABILITY.

### SUGGESTED SOLUTION

SNUBBERS AND RESTRAINTS DESIGNED WITHOUT MOVING PARTS WHOSE FUNCTIONAL OPERATION DEPENDS ON THE INHERENT PROPERTIES OF THE MATERIAL USED.

File: RD 4.2



CAUSES OF LEAKAGE  
(SOURCE - ABNORMAL OCCURRENCE REPORTS)

SEAL FAILURES

- DEGRADED U-CUP
- SEAL DETERIORATION
- BRITTLE AND BROKEN O-RINGS
- CUT OR NICKED O-RINGS
- MISSING O-RINGS
- LEAKING GASKETS

LEAK PATH

- SCORED PISTON
- FAILURE OF ALEMITE FILLER PLUG SEAL
- LOOSE FITTINGS
- LOOSE LOCK NUTS
- LOOSE ADJUSTING SCREWS
- ELBOW CONNECTING SNUBBER TO RESERVOIR DAMAGED
- LEAKAGE THROUGH WEEP HOLE  
(DAMAGED ACCUMULATOR SEAL)
- RESERVOIR BROKE AT CONTROL VALVE  
(MALLEABLE STREET ELBOW FAILED)
- HYDRAULIC FITTINGS BETWEEN CONTROL VALVE  
AND CYLINDER BROKE
- FEEDPIPE TO RESERVOIR BROKE
- VALVE AND CYLINDER BROKE
- CALIBRATION PLATE MISALIGNMENT
- POOR DESIGN OF ROD PACKING RING

## CAUSES OF FAILURE

### COMPONENT FAILURE

- FROZEN PISTON
- MISALIGNMENT OF CONTROL ROD ASSEMBLY
- SNUBBER ROTATED AROUND ATTACHMENT
- CONTROLLER MISADJUSTMENT - BROKE AT POINT OF ATTACHMENT
- PISTON ROD TORE OUT OF PIPE CLEVIS
- FAILURE BETWEEN PISTON AND EXTENSION ROD
- THREADED EXTENSION TO CYLINDER BENT SO RESERVOIR OUT OF POSITION
- SNUBBER PAINTED IN VIOLATION OF INSTRUCTIONS - PAINT CHIPPED AS ROD MOVED AND CHIPS LOCKED PISTON TO BUSHING



# SNUBBERS AND RESTRAINTS ON LIGHT WATER REACTORS HISTORY OF LEAKAGE AND FAILURES

NUMBER OF EVENTS BY TYPE REACTOR	NUMBER OF EVENTS BY YEAR		TYPE OF EVENT FOR HYDRAULIC SNUBBERS
BWR - 75	1971	2	EMPTY 186
PWR - 32	1972	4	PARTIALLY EMPTY 298
	1973	19	STATUS UNSURE 22
	1974	49	
	1975	29	
	1976	9	

# SPECIFIC INCIDENTS OF DAMAGE TO COMPONENTS

<u>COMPONENT</u>	<u>NUMBER DAMAGED</u>	<u>NUMBER BROKEN</u>	<u>PULLED OUT OF WALL, ETC.</u>
PIPE HANGERS	11	11	6
RESTRAINTS/SNUBBERS	8	4	-
PIPE/VALVES	2	4	-

# INCIDENTS OF DAMAGE TO SNUBBERS AND RESTRAINTS (1971-1975)

TYPES OF DAMAGE - 48 INCIDENTS WHERE COMPONENTS WERE  
BENT, BROKEN, OR OTHERWISE DAMAGED

<u>CAUSES OF DAMAGE</u>	<u>TOTAL</u>	<u>BWR</u>	<u>PWR</u>
WATER HAMMER	19	11	8
CONSTRUCTION-INSTALLATION DEFICIENCY OR ERROR	11	6	5
DESIGN DEFICIENCY OR ERROR	6	3	3
VALVE CLOSURE - TURBINE TRIP	3	2	1
VIBRATION FATIGUE	2	2	0
UNKNOWN	4	1	3
	<u>45</u>	<u>25</u>	<u>20</u>



TYPICAL TECHNICAL SPECIFICATION REQUIREMENTS  
FOR HYDRAULIC SNUBBERS (3.12)

APPLICABILITY

- APPLIES TO THE OPERATIONAL STATUS OF SAFETY-RELATED HYDRAULIC PIPE RESTRAINTS (SNUBBERS).

OBJECTIVE

- TO DEFINE THE LIMITING CONDITIONS FOR OPERATION APPLIED TO THE OPERABILITY OF SAFETY-RELATED HYDRAULIC SNUBBERS.

## TYPICAL TECHNICAL SPECIFICATION REQUIREMENTS FOR HYDRAULIC SNUBBERS (3.12)

### SPECIFICATION

1. DURING ALL MODES OF OPERATION EXCEPT COLD SHUTDOWN AND REFUELING SHUTDOWN, ALL HYDRAULIC SNUBBERS LISTED IN TABLE 3.12-1 SHALL BE OPERABLE EXCEPT AS NOTED IN 3.12.2 THROUGH 3.12.4 BELOW.
2. FROM THE TIME THAT A HYDRAULIC SNUBBER IS DETERMINED TO BE INOPERABLE, CONTINUED REACTOR OPERATION IS PERMISSIBLE ONLY DURING THE SUCCEEDING 72 HOURS. IF THE SNUBBER IS MADE OPERABLE WITHIN THE 72 HOUR TIME FRAME, REACTOR SHUTDOWN IS NOT REQUIRED.
3. IF THE REQUIREMENTS OF 3.12.1 AND 3.12.2 CANNOT BE MET, AN ORDERLY SHUTDOWN SHALL BE INITIATED AND THE REACTOR SHALL BE IN A COLD SHUTDOWN CONDITION WITHIN 36 HOURS.
4. IF A HYDRAULIC SNUBBER IS DETERMINED TO BE INOPERABLE WHILE THE REACTOR IS IN THE COLD SHUTDOWN MODE OR THE REFUELING MODE, THE SNUBBER SHALL BE MADE OPERABLE PRIOR TO REACTOR STARTUP.

PLANTS HAVING DAMAGED COMPONENTS OR DESIGN/  
CONSTRUCTION DEFICIENCIES

<u>PWR</u>		<u>BWR</u>
CONNECTICUT YANKEE	3	FITZPATRICK 4
DONALD C. COOK	1	ARNOLD 3
ZION-1	1	COOPER 3
RANCHO SECO	1	PEACHBOTTOM-3 2
PALISADES	2	PEACHBOTTOM-2 1
ARKANSAS NUCLEAR 1, NO.1	1	QUAD CITIES-1 2
MILLSTONE-2	1	VERMONT YANKEE 1
INDIAN POINT-2	1	DRESDEN-2 1
ARKANSAS NUCLEAR 1, NO.2	1	BROWNS FERRY-1 2
TURKEY POINT-3	3	BRUNSWICK-2 1
SURRY-2	2	MILLSTONE-1 2
ROBINSON	2	DRESDEN-3 1
SURRY-1	1	PILGRIM-1 1
	—	LaCROSSE BOILING WATER 1
	20	25



## REQUIREMENTS

1. DAMPEN FLOW-INDUCED VIBRATION TO MINIMIZE FATIGUE - ELASTIC RANGE OF DAMPER (SNUBBER, RESTRAINT)
2. CAPABLE OF DAMPING SEISMICALLY-INDUCED VIBRATIONS TO ACCEPTABLE AMPLITUDES. ELASTIC-PLASTIC RANGE OF DAMPER
3. CAPABLE OF PREVENTING SEVERE DAMAGE OR FAILURE OF A PIPE DUE TO WATER SLUGGING OR WATER HAMMER - ELASTIC-PLASTIC TO PLASTIC RANGE OF DAMPER
4. CAPABLE OF CONTROLLING PIPE WHIP IN THE EVENT OF A DOUBLE-ENDED PIPE BREAK OR AN AXIAL SPLIT - SNUBBER TO FUNCTION IN ELASTIC-PLASTIC TO FULLY PLASTIC RANGE IN BOTH TENSION AND COMPRESSION FOR A LIMITED NUMBER OF HIGH AMPLITUDE CYCLES

DAMPER (SNUBBER, RESTRAINT) CRITERIA AND PROBLEMS  
REQUIRING SOLUTION

1. DEVELOP ACCEPTABLE ANCHORING DEVICES TO ENSURE FAILURE WILL NOT OCCUR AT THE ANCHOR
2. SNUBBER MUST NOT BIND PIPES AXIAL MOVEMENT DURING HEAT UP AND COOL DOWN
3. SNUBBER MATERIAL MUST NOT BE DEGRADED BY ENVIRONMENTS; e.g., NO STRESS CORROSION, PITTING CORROSION, ETC.
4. SNUBBER MATERIAL MUST BE CAPABLE OF NON-DESTRUCTIVE EXAMINATION, ALTHOUGH IT IS HOPED SUCH EXAMINATION WILL BE LIMITED
5. SNUBBER DESIGNS SHOULD BE OPTIMIZED SO AS NOT TO INTERFERE EXCESSIVELY WITH MAINTENANCE AND IN-SERVICE INSPECTION
6. WHILE INITIAL DESIGNS AND TESTING SHOULD EMPHASIZE PIPING IN THE DIAMETER RANGE 4-15 INCHES, THE SNUBBERS SHOULD BE AMENABLE TO SCALE-UP TO LARGER SIZES
7. SNUBBERS SHOULD BE PROVEN TO BE OF COMPARABLE OR BETTER RELIABILITY TO HYDRAULIC OR MECHANICAL SNUBBERS TO SPECTRUM OF EVENTS CITED AND BE LESS EXPENSIVE

WATER HAMMER

<u>PLANT</u>	<u>YEAR</u>	<u>TYPE DAMAGE</u>
D.C. Cook	1976	Hydraulic snubbers on 14" feedwater line damaged, including failure of hydraulic fittings and reservoir feedpipe.
Brunswick-2	9/75	Three cases of water hammer occurred during a one month period in the RHR system. Subsequent inspections revealed cracked grouting on certain pipe supports. Only minor pipe movement and limited damage to pipe supports occurred.
Fitzpatrick	1975	Restraints and supports on containment spray header damaged; one hydraulic snubber broken.
Fitzpatrick	9/75	Several (3 of 4) restraints on HPCI steam line damaged by water hammer.
Fitzpatrick	1975	Restraints of RHR steam supply to HX failed by pulling from wall.
Palisades	1974	Horizontal pipe restraint on suction line of LPCI failed by pulling loose from pillar (4-5/8" bolts).
Arnold	1974	Restraint bolting damaged in core spray system.
Rancho Seco	1974	Seismic support bolting damaged in feedwater line to steam generator.
Fitzpatrick	1974	RHR pipe moved up to 10 inches; seismic supports dampened.
Zion-1	1974	Hanger broken on auxiliary feedwater pump pipe. Rainwater entering exhaust line caused water hammer.
Surry-2	1974	Flashing and water hammer damaged pipe restraints on three safety injection discharge lines grouting concrete supports.
Browns Ferry-1	1974	Operator error moved HPCI pipe, broke 3 pipe restraints, bent and damaged others, fractured journal.



WATER HAMMER (CONTINUED)

-2-

Millstone-1            1973

Hangers on Torus ring header for 18-inch LPCI system damaged due to sudden injection of 260 psi water into line while empty.

Indian Point-2        11/73

A turbine trip due to a high water level in a steam generator (at 7% power) caused interruption of normal feedwater flow causing the level in another steam generator to drop to where the reactor tripped on low-low level. After reactor trip a continued decrease in level was observed accompanied by a rise in containment temperature and humidity. Investigation showed that the A-106 Grade C 18-inch main feedwater pipe to one steam generator had cracked 180° circumferentially at the weld attaching the pipe to the penetration inside containment. Shaking accompanied by a loud noise at about the time of reactor trip. A water-steam reaction in the horizontal feedwater line adjacent to the steam generator was considered to be responsible for the (water slug) leaks. After pipe failure steam water impingement on the containment caused localized bulging of the liner. Corrective actions included shortening of the feedwater line, installation of feeding jets, and J-tube modifications of the feeding.

Subsequent to the initial failure and prior to the complete "fix", other water hammers occurred at Indian Point-2 under conditions of low feedwater flow when the water level fell below the spargers; simultaneous with the recovery of the sparger with water (covering and sealing holes in the bottom of the sparger).

WATER HAMMER (CONTINUED)

-3-

<u>PLANT</u>	<u>YEAR</u>	<u>TYPE DAMAGE</u>
Surry	10/72	Water hammer while steam generators being fed by auxiliary feedwater system damaged main steam line, check valve and local displacement of feedwater piping.
Quad Cities-1	4/72	RHR's seismic restraints and pipe hangers damaged due to water hammer resulting from improper venting and air accumulation. Three seismic restraint damaged, a spring hanger bottomed, grout chipped on another; four hangers damaged.
Vermont Yankee	11/71	Water hammer in HPCI turbine exhaust piping. Cause - steam condensation in turbine exhaust line following a test, pulling water from suppression pool at high velocity. Vacuum breaker installed to prevent recurrence.
Dresden-2	1970	Water behind valve in HPCI line accelerated and dented 10-feet of pipe, breaking or bending several restraints and snubbers.
Turkey Point 3 & 4		Three cases of water hammer in feed-water piping from steam generators to feedwater check valves developed leaks in bonnets and anchor bolts pulled out of concrete.

CONSTRUCTION INSTALLATION ERROR/DEFICIENCY

<u>PLANT</u>	<u>YEAR</u>	<u>TYPE DAMAGE</u>
Arkansas Nuclear 1, No. 2	1976	Cracks in main steam pipe restraints due to welding procedures or to lamellar tearing.
Millstone-2	8/75	A mechanical snubber on pressurizer locked up during hot functional test, resulting in bending shaft on adjacent snubber on same line. (International Nuclear Safeguards Snubber). Snubber had been installed with preset screw in place. Dynamic loading of plant heatup caused setscrew to shear.
Connecticut Yankee	6/75	Only one of four pressurizer restraint guides were installed properly. The other three did not line up properly with embedded plates so only six of eight bolts and 1 of 2 dowel pins were installed. 16 of 24 bolts on ring girder were never tightened enough to compress lock washers (poor workmanship). Analysis revealed pressurizer seismic restraints would have failed if earthquake had occurred.
Cooper	1975	Hanger on RHR system broke at weld HAZ due to incorrect installation of hanger. Weld made along edge of beam flange rather than across flange.
Cooper	1975	Circumferential weld on snubber extension to anchor bracket failed due to lack of weld penetration between pipe and flange plates.
Arnold	1975	Stem on snubber broke due to bracket installed 90° from correct orientation so movement of steam exhaust line caused steam to contact bracket and break due to overload.
Arnold	1974	Restraining pin not removed from hanger after hydro test heatup, movement limited, no specific damage.



CONSTRUCTION INSTALLATION ERROR/DEFICIENCY (CONTINUED)

<u>PLANT</u>	<u>YEAR</u>	<u>TYPE DAMAGE</u>
H.B. Robinson	1973	Main steam line seismic restraint moved 2-3 inches breaking grouting around studs and causing bending of restraints due to failure of pipe shoe to slide on mating surface.
Peachbottom	1972	Poor field welds, low preheat on 2 main line restraints.
H.B. Robinson	1970	During hot functional testing a 6-inch pipe nozzle between pressurizer main steam line and safety valve failed completely due to crack initiated at excessively machined taper.
Quad Cities	1972	Four pipe hangers on ECCS 24° Torus suction header failed; bolts sheared.

DESIGN ERROR/DEFICIENCIES

<u>PLANT</u>	<u>YEAR</u>	<u>TYPE DAMAGE</u>
Peachbottom	1975	Snubbers restrained thermal motion after dynamic load - design.
Palisades	1975	188 restraints replaced or modified on lines > 2.5 in.
Arkansas Nuclear 1, No. 1	1974	Several hanger rods bent during a pipe shock test. Corrected by adding snubbers.
Browns Ferry-1	1974	15 of 16 pipe hangers on Torus header failed due to design deficiency (bolts failed), header dropped on several drywell vents.
Turkey Point-3	1972	Three or four safety valves on main steam line header blew off and split head due to system not designed for reaction forces under dynamic loads.
LaCrosse Boiling Water Reactor	1968	Uncorrected thermal expansion caused constant force to bend hanger and feedwater pipe lifted ~ 1".

### VALVE CLOSURES - TURBINE TRIPS

<u>PLANT</u>	<u>YEAR</u>	<u>TYPE DAMAGE</u>
Turkey Pt.-3	1975	Spurious closure of MSIV at full power apparently generated enough transient load to distort spring hanger on main steam line.
Pilgrim-1	1972	Restraint on steam line torn from support so others bent. Turbine trip.
Millstone-1	1971	Supports damaged - severe movement of main steam and bypass lines. Turbine trip.

### VIBRATION FATIGUE

Cooper	1976	Four seismic pipe hangers failed at bolt holes due to fatigue induced by pipe vibration. Hangers designed close to limits so any excess loading would cause flexing at support bolts.
Dresden-3	8/73	Vibration in piping transmitted thru two (empty) hydraulic snubbers and caused failure at a weld attaching 3" pipe stub to larger pipe. Fillet weld was stress riser.



UNKNOWNNS

<u>PLANT</u>	<u>YEAR</u>	<u>TYPE DAMAGE</u>
Peachbottom	11/75	Rigid pipe support on RHR line broken - no cause given.
Connecticut Yankee	1975	Three steam generator holddown bolts broken - alarm system not actuated to detect such breaks.
Connecticut Yankee	1975	Pipe hangers (attachments) on steam generator feedwater pipe broken. No known incidents of overstressing.
Surry 1 & 2	1973	Snubbers on 6" pressurizer collector line broken. Pipe moved ~ 2".